Estimating the contribution of influenza, COVID-19 and extreme cold weather to excess mortality: a working paper update for 2024

Winter 2023 to 2024, with backdated estimates to 2012 to 2013

Using an adapted FluMOMO model

Nick Andrews[1]
Conall Watson[1]

[1] Immunisation and Vaccine-Preventable Diseases Division, UK Health Security Agency

1. Introduction

The burden of influenza-related mortality has been estimated for many years based on assessing all-cause mortality and influenza incidence. Spikes of excess mortality are often seen when influenza circulation is at its peak or highest in a given winter period. This has led to regression models being developed that model a baseline mortality along with an attributable influenza component to estimate contribution of influenza. The baseline model is typically a Serfling (sine/cosine wave) with a trend (1). More recently models have been extended to take into account extreme weather such as the FluMOMO model (2).

The FluMOMO model has been used by the UK Health Security Agency (UKHSA) for many years to estimate influenza-related mortality and is published in annual reports (3 to 6). In 2023 the model was adapted to include COVID-19 and to deal with the very high level of mortality in the first waves of COVID-19. The temperature modelling was also slightly changed. Full details of the new model are given in the working paper (7).

For the 2023 to 2024 winter the adapted model was run again using data from week 40 2012 to week 13 2024. This produced estimates of attributable mortality for the 2023 to 2024 winter and also updated estimates for the previous years. In this paper we address some small changes made to the data used in the model and compare the output to the model run in 2023.

2. Data used for the 2024 model

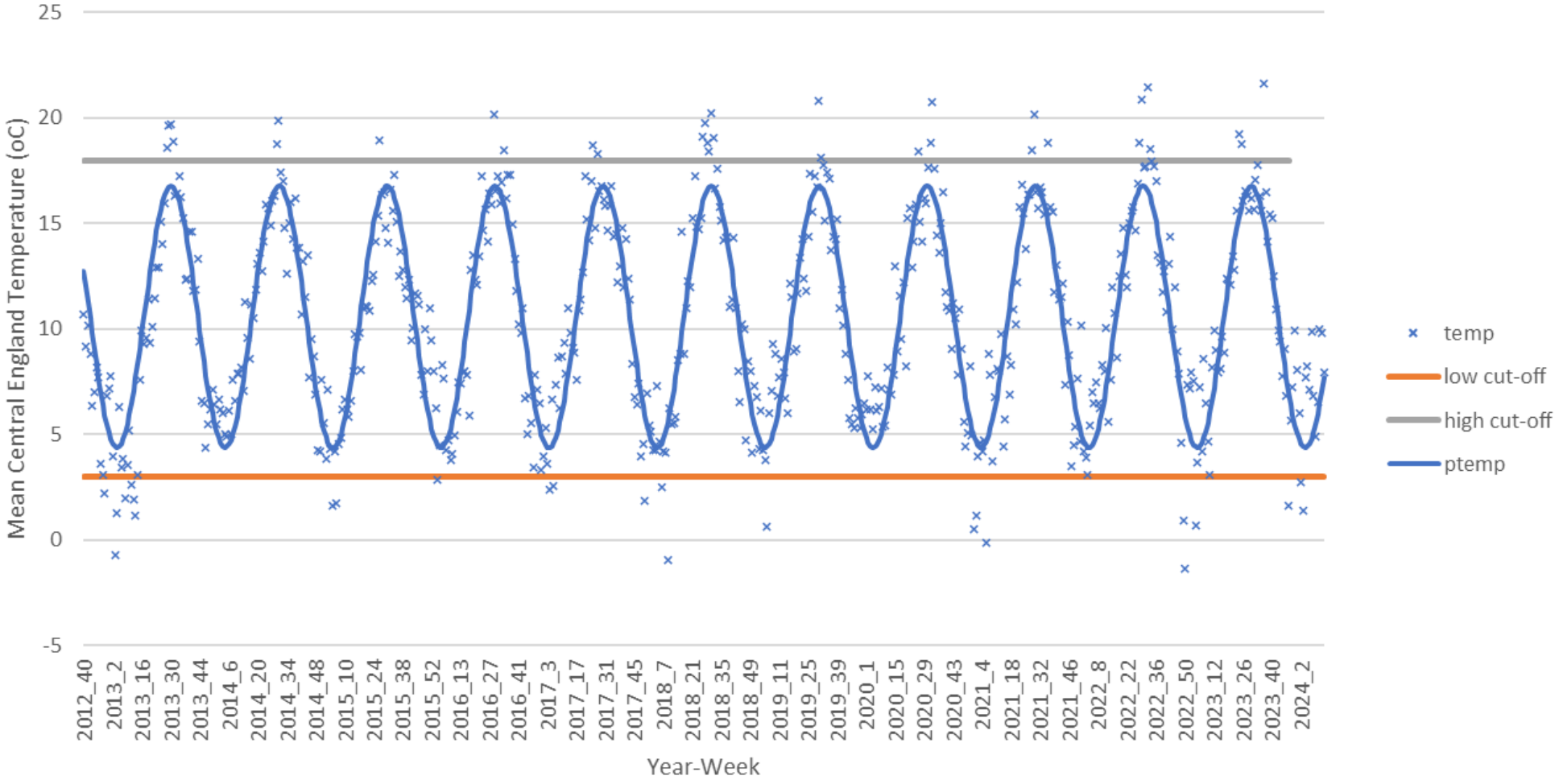
The all-cause mortality data wwas the same as used in the 2023 model, but updated to week 13 of 2024 based on the EuroMOMO registration-delay corrected deaths from the model run in week 19 of 2024 (8). The data was stratified by week of death and age group (under 5, 5 to 14, 15 to 64, 65 and over).

Influenza activity by age group was included in the model using data on rates of influenza like illness (ILI) extracted from the Royal College of General Practitioners (RCGP) Research and Surveillance Centre database. This was a new extract and had some differences from the 2023 data which was based on historic weekly rates from RCGP compiled each year at UKHSA. The ILI rates were multiplied by the overall weekly swab influenza positivity rates from samples taken by a subset of RCGP practices to give the influenza indicator.

As in 2023 the temperature element used thresholds at 3°C (low) and 18°C (high). The Met Office Hadley Centre Central England Temperature (CET) data set was used to create a weekly national mean temperature to measure against (9). The difference from the threshold was calculated when temperatures went beyond them, so, for example, a weekly mean CET of 1°C was given a parameter value of 2 (3°C minus 1°C).

Figure 1 shows the temperature data, with thresholds just over 1°C above or below the modelled summer maximum and winter minimum temperature indicated. The thresholds identify several high weeks each summer and low weeks most winters to represent extreme weeks.

Figure 1. Mean Central England temperature (with fitted line and the cut-offs used for extreme temperature)



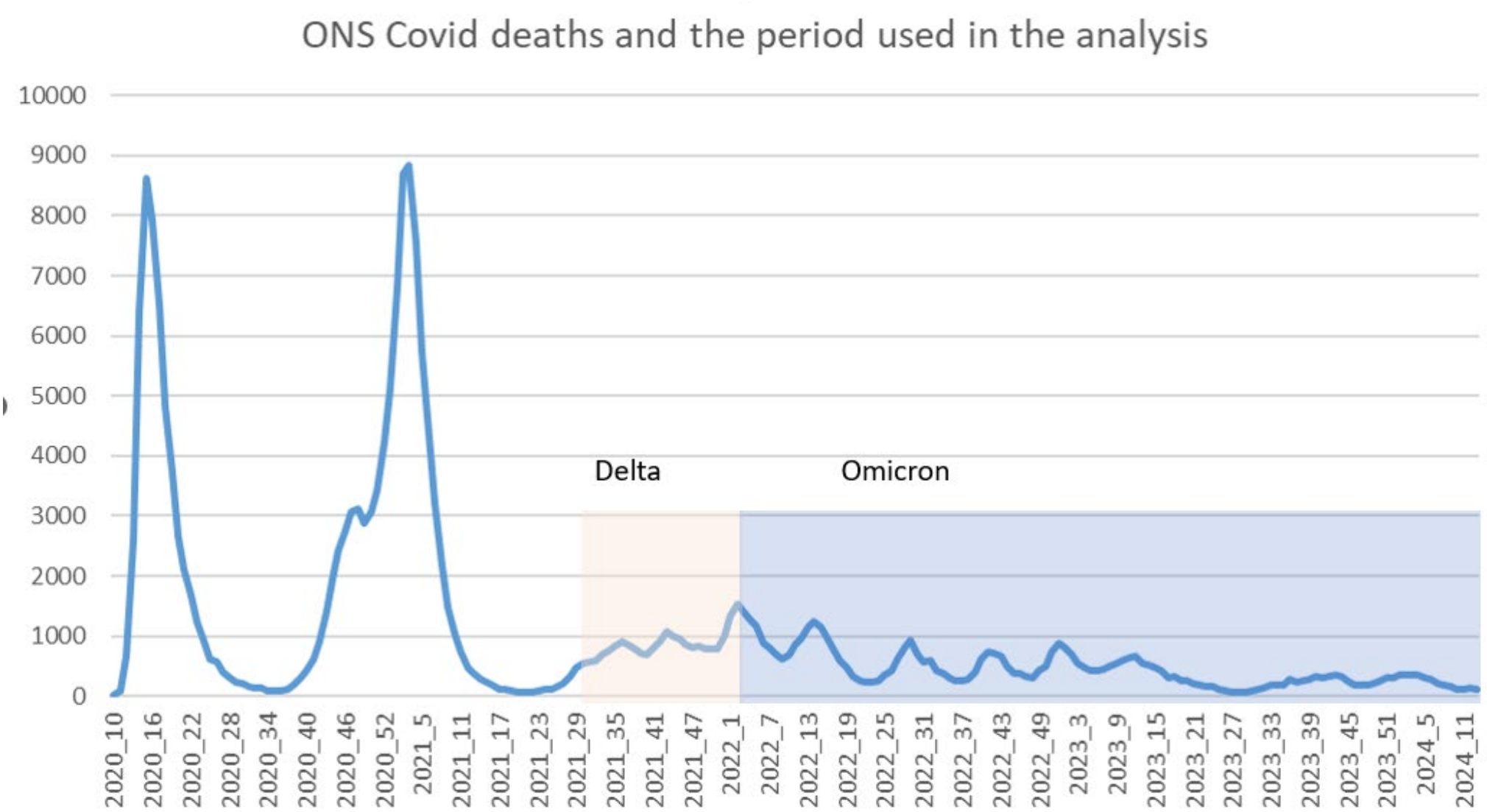
As was done in the 2023 model, to address the initial 2 largest COVID-19-related spikes in number of deaths, and the low number in the weeks following the second spike, the period from week 13 2020 to week 26 2021 was given zero weight when fitting the models and excess mortality in the winter of 2020 to 2021 was not estimated. To further down-weight any remaining outliers, the model was re-weighted once with standardised residuals <-2 or >2 given a weight of 1/(residual^2).

Also as done in 2023, to account for COVID-19 in the period from week 27 2021 weekly ONS COVID-19 death occurrences were included as an explanatory variable in the model. These were split into 2 series comprising deaths assumed to be due to the Delta variant from week 27 2021 to week 1 2022, and deaths assumed to be due to the Omicron variant from week 2 2022 onwards, meaning that 2 COVID-19 parameters for the contribution of Delta and Omicron to all-cause mortality were included in the model. Figure 2 shows the numbers of COVID-19 deaths with the Delta and Omicron periods that were included in the models highlighted. The COVID-19 deaths were extracted in week 19 of 2024 back to the start of the pandemic and did include some additional deaths throughout the pandemic that were registered late.

The model of all-cause mortality therefore had explanatory variable for heat (1 parameter), cold (3 parameters to allow lags of up to 2 weeks), influenza (36 parameters to cover 12 seasons and within each season lags of up to 2 weeks), COVID-19 (2 parameters to cover Delta and Omicron), and baseline (6 parameters to cover a constant, a trend and sine and cosine waves with periods 26 and 52). Models were run separately for each age group and fitted using Poisson regression with a rescaling of standard errors to allow for over-dispersion.

Total deaths were calculated by summing across the 4 age groups. The 95% confidence interval (CI) for this was based on the standard errors of each of the estimates for each age group.

Figure 2. COVID-19-related deaths (ONS death certificate) week 10 2020 to week 13 2024



3. Results

3.1. Descriptive

Results are based on deaths to week 13 2024, extracted in week 19 2024 to allow time for data to be more complete and less dependent on corrections for delayed death registration. The influenza indicator is shown in Figure 3. Activity was low in 2023/2024 compared to 2022/2023. Note however that is the timing within each season of influenza activity compared to mortality spikes that matters, not the overall level within any year.

The modelled contribution of influenza, COVID-19 and temperature, when looking at the model with all ages combined, is shown in Figure 4. Note this is not the model used for all age estimates, as that combines across the individual ages. Figure 5 shows the most recent 2 winters and does combine across ages here to get the totals.

Figure 3. Influenza activity incidence by year 2012 to 2024

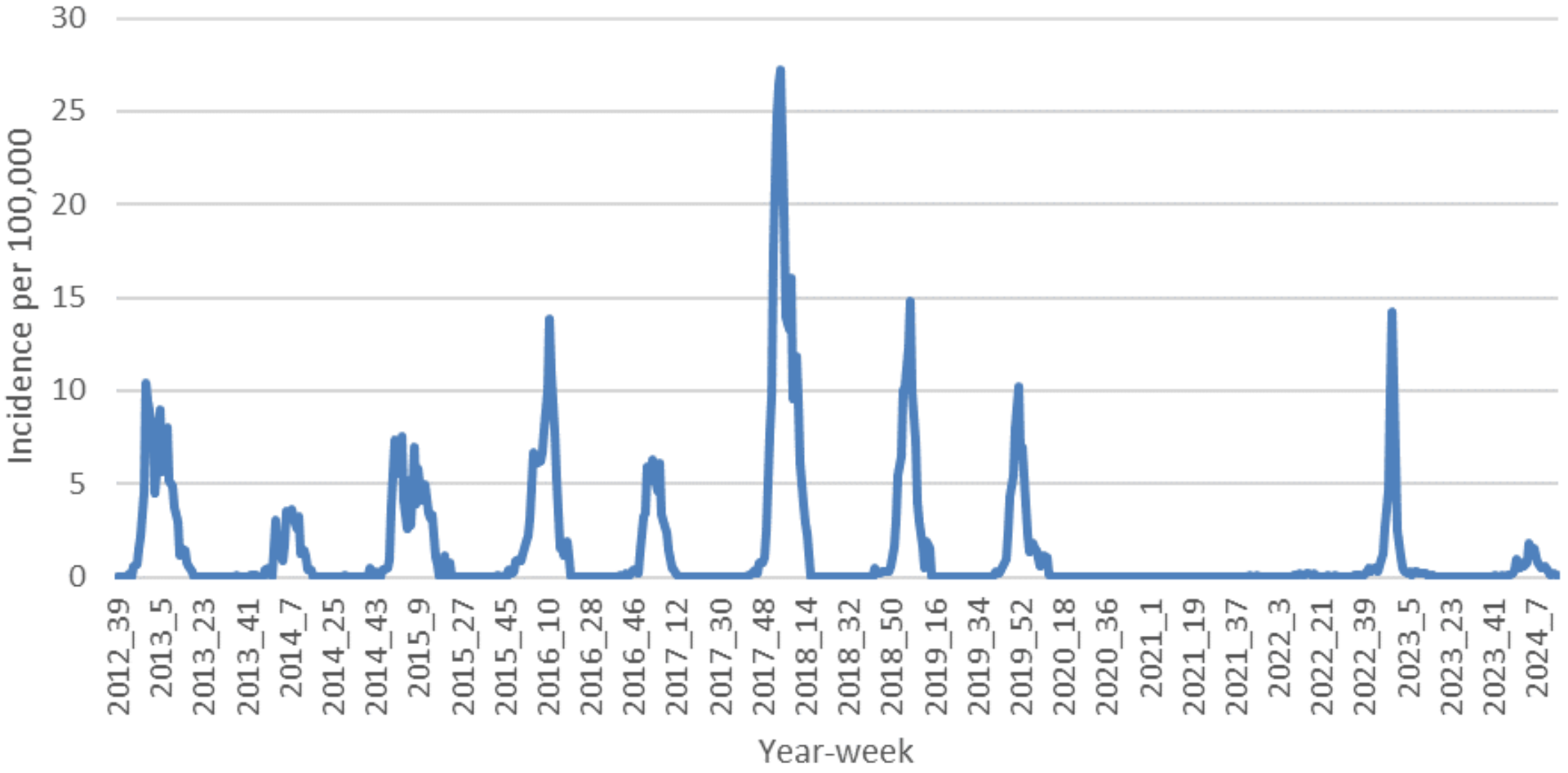
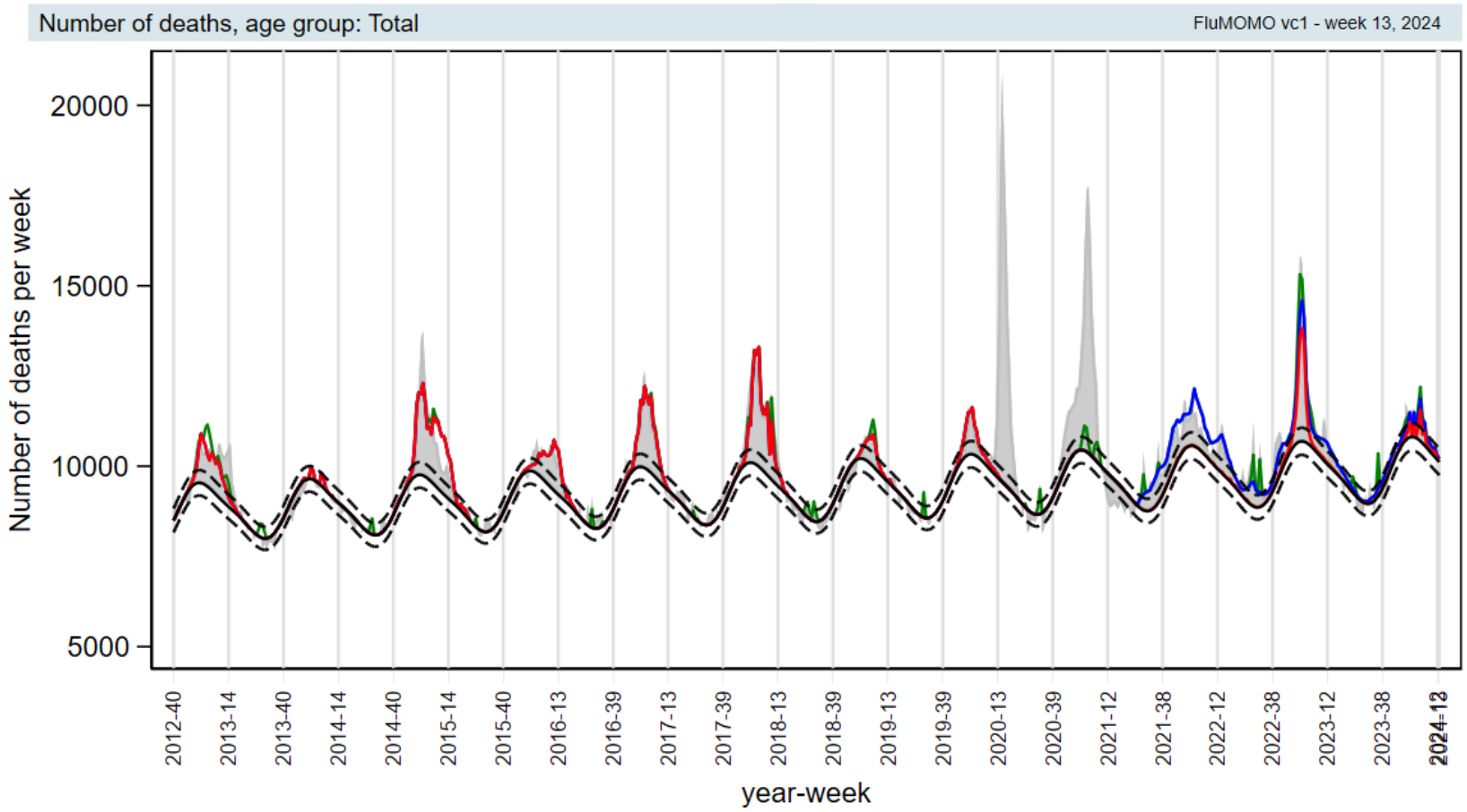
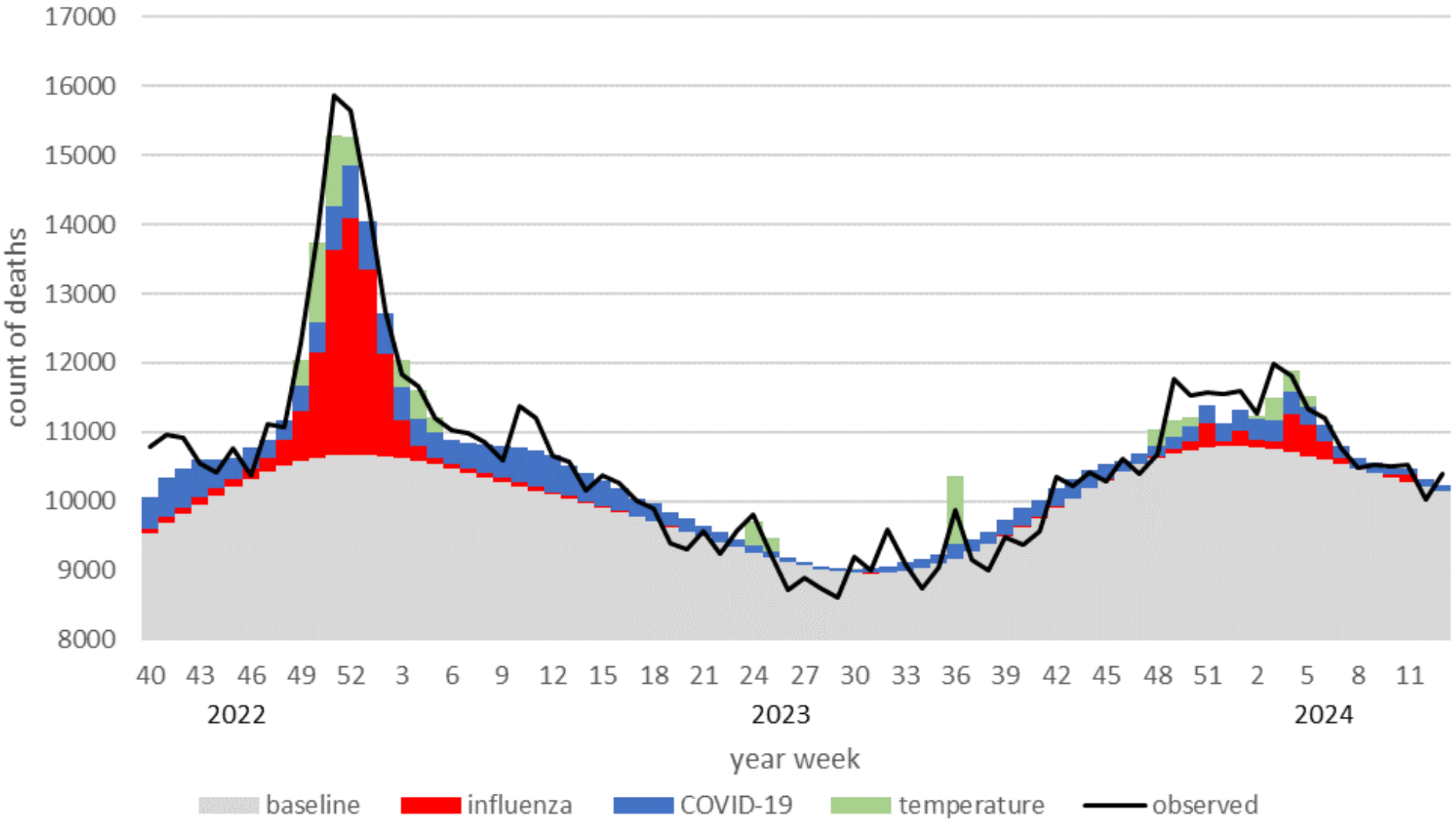


Figure 4. Modelled excess mortality



Black line: baseline, dotted black line: 95% confidence interval
Red: Effect of Influenza Activity (IA)
Blue: Effect of Covid (on top of IA)
Green: Effect of excess temperature (on top of IA & Covid)
Deaths week12 2020- week26 2021 excluded from modelling
Note: Negative effects of IA and COVID are not shown

Figure 5. Modelled excess with focus on data since week 40 2022



3.2. Full results from the model

The age split results and total are shown in Table 1 below for 2023 to 2024. Values in paratheses are 95% CI. They do not include uncertainty from model specification. The 2023 working paper sensitivity analyses demonstrated results for temperature and to a lesser extent COVID-19 can vary depending on the model.

Table 1. Estimates of mortality by age 2023 to 2024

Age	Influenza	COVID-19	Cold	Unexplained	Total
0 to 4 years	87 (73 to 102)	0	11 (7 to 16)	1	100
5 to 14 years	23 (16 to 31)	17 (14 to 21)	0	-9	32
15 to 64 years	188 (156 to 222)	397 (368 to 427)	77 (59 to 96)	63	724
65 and over	2,478 (2,321 to 2,639)	5,043 (4,911 to 5,177)	1,350 (1,252 to 1,450)	-92	8,779
Total	2,776 (2,613 to 2,939)	5,457 (5,321 to 5,593)	1,438 (1,337 to 1,539)	-37	9,635

Note that estimates in children should be treated with caution, as the method is unlikely to be reliable enough to estimate such small excesses with accuracy.

The all-age total estimates by year are shown in Table 3 below, including unexplained excess and total. Unexplained is negative if the estimated excess from influenza, COVID-19 and cold is more than the observed total excess above the baseline.

Table 2. Estimates of attributable all-cause mortality by season (week 40 to week 20)

Year	Influenza	COVID-19	Cold	Unexplained	Total
2012/13	14,788	0	4,125	4,239	23,152
2013/14	1,412	0	0	-5,341	-3,929
2014/15	30,703	0	1,046	-638	31,112
2015/16	13,091	0	63	861	14,014
2016/17	19,244	0	432	2,912	22,588
2017/18	26,557	0	2,302	5,599	34,457
2018/19	5,670	0	999	-4,306	2,364
2019/20	8,583	n/a	0	53,923	62,506

Year	Influenza	COVID-19	Cold	Unexplained	Total
2020/21	n/a	n/a	n/a	n/a	n/a
2021/22	442	29,058	0	-4,840	24,660
2022/23	15,465	14,077	3,963	2,954	36,457
2023/24	2,776	5,457	1,438	-37	9,635

Comparison to the 2023 model results is shown in Table 3.

Table 3. Estimates of attributable mortality from the models run in 2024 and 2023

	Influenza		COVID-19		Cold	
Year	2024 model	2023 model	2024 model	2023 model	2024 model	2023 model
2012/13	14,788	9,021	0	0	4,125	5,748
2013/14	1412	167	0	0	0	0
2014/15	30,703	29,965	0	0	1,046	1,452
2015/16	13,091	12,223	0	0	63	88
2016/17	19,244	17,769	0	0	432	597
2017/18	26,557	22,419	0	0	2,302	3,215
2018/19	5,670	5,144	0	0	999	1,391
2019/20	8,583	8,800	n/a	n/a	0	0
2020/21	n/a	n/a	n/a	n/a	n/a	n/a
2021/22	442	104	29,058	25,971	0	0
2022/23 [note 1]	15,465	14,623	14,077	10,345	3,963	5,533

Note 1: 2022/2023 was to week 13 for the 2023 model and to week 20 for the 2024 model.

4. Comment

Influenza-related mortality is estimated to be around 2,800 deaths for winter 2023 to 2024. This is lower than most previous seasons. Because the effects of cold on mortality continue over a few weeks (hence the inclusion of lag terms) and because the Omicron COVID-19 waves have not shown large spikes, the method is less well suited to provide reliable estimates of the mortality contribution of these factors. The estimates mortality due to COVID-19 in 2023 to 2024 is about 5,500 which is somewhat less than the actual COVID-19 death numbers used in the model (which was 6,548). This may be model misspecification, but equally could be because a proportion of deaths with COVID-19 on the death certificate were not due to COVID-19 (10). For temperature-related mortality, the 1,400 estimate is based on 3 cold weeks, although these were less cold than the 3 cold weeks in 2022 to 2023. This estimate is contingent on the definition of cold used. If thresholds were changed to assign more weeks to be cold weeks then it is likely more deaths would be attributed to severe cold weather, however the aim was to look at extreme cold weather only.

When updating the model fit in 2024 there were some notable changes to past estimates. Attribution to influenza and COVID-19 increased a little in most seasons. In particular in 2012 to 2013 there was a larger increase which is due to come changes in the influenza indicator for that year. COVID-19 increases are partly due to additional registered deaths now being included, strengthening the link between observed and excess deaths. The estimates for cold weather have decreased. This is likely because the cold periods in 2023 to 2024 did not correlate very much with mortality increases, weakening the overall relationship which is applied for the whole time series. This lower attribution to cold may also explain some increases in the influenza and COVID-19 attribution. The changes indicate that the estimates are sensitive to model specification. Nevertheless the 2022 to 2023 Influenza estimate of about 15,000 attributable deaths remains broadly similar. The increase in the COVID-19 attribution for 2022 to 2023 is mainly due to the added period of 7 weeks (taking the period to week 20) for the updated 2024 analysis when COVID-19 was still circulating. The estimates in this updated 2024 analysis should now be regarded as the best estimates.

There are other factors not attributed that may contribute to winter mortality, such as pressures on acute health services and the circulation of other infections. The model methods assume these factors are captured in the seasonal component. The influenza estimates, in particular, are quite robust to other factors (unless those factors cause spikes at the same time as the influenza spike). Whilst further possible causes of winter mortality could be modelled the methodology is unlikely to give reliable estimates unless effects are large and occur in concentrated periods.

References

1. Serfling R. Methods for current statistical analysis of excess pneumonia-influenza deaths. Public Health Reports (1896) 1963: volume 78, issue 6, pages 494 to 506
2. Nielsen J, Krause T, Molbak K. Influenza-associated mortality determined from all-cause mortality, Denmark 2010/11-2016/17: The FluMOMO model Influenza and Other Respiratory Viruses 2018: volume 12 issue 5, pages 591 to 604
3. UKHSA. 'Surveillance of influenza and other seasonal respiratory viruses in the UK, winter 2021 to 2022 and previous reports backdated to 2011 to 2012 'Public Health England Annual flu reports, Health Protection Agency Influenza (viewed 22 May 2023)
4. Pebody RG, Green HK, Warburton F, Sinnathamby M, Ellis J, Mølbak K, Nielsen J, de Lusignan S, Andrews N. 'Significant spike in excess mortality in England in winter 2014 to 2015: influenza the likely culprit' Epidemiology and Infection 2018: volume 146, issue 9
5. Pebody RG, Warburton F, Andrews N, Sinnathamby M, Yonova I, Reynolds A, Robertson C, Cottrell S, Sartaj M, Gunson R, Donati M, Moore C, Ellis J, de Lusignan S, McMenamin J, Zambon M. 'Uptake and effectiveness of influenza vaccine in those aged 65 years and older in the UK, influenza seasons 2010/2011 to 2016/2017' Eurosurveillance 2018: volume 23, issue 39
6. Sinnathamby MA, Warburton F, Reynolds AJ and others. 'An intercountry comparison of the impact of the paediatric live attenuated influenza vaccine (LAIV) programme across the UK and the Republic of Ireland (ROI), 2010 to 2017' Influenza and Other Respiratory Viruses 2023: volume 17. Issue 2
7. Andrews N, Clare, T, Sinnathamby M, Watson, C. 'Working paper: estimating the contribution of influenza, COVID-19 and extreme cold weather to excess mortality, winter 2022 to 2023' (2023)
8. The EuroMOMO model: Methods and Rationale. EuroMOMO Network (viewed 22 May 2024)
9. Met Office Hadley Centre Central England temperature data sets (viewed 22 May 2024)
10. Seghezzo G, Allen H, Griffiths C, Pooley J, Beardsmore L, Caul S, Glickman M, Clare T, Dabrera G, Kall M. 'Comparison of 2 COVID-19 mortality measures used in the pandemic response in England' (2023)